Energy, Mines and Resources Canada

Énergie, Mines et Ressources Canada

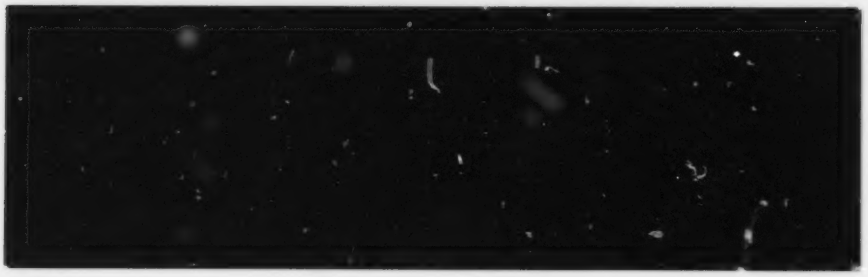
CANMET

Canada Centre for Mineral and Energy Technology

Centre canadien de la technologie des minéraux et de l'énergie

Metals Technology Laboratories

Laboratoires de la technologie des métaux



Canada

METALS TECHNOLOGY LABORATORIES

CORROSION ANALYSIS OF TANK TESTING FLUX-CORED ARC WELD DEPOSIT BY LASER SCANNER AND CONTOUR TRACER

A.W. LUI AND J. MCGOEY

MTL 90-47(TR)

MICROMEDIA

14 pp

CANMET

91-02420/

METALS TECHNOLOGY LABORATORIES
REPORT 90-47(TR)

CORROSION ANALYSIS OF TANK TESTING FLUX-CORED ARC WELD DEPOSIT BY LASER SCANNER AND CONTOUR TRACER

by

A.W. Lui and J. McGoey

ABSTRACT

Fifteen flux-cored arc weldments (FCAW) with various fluxes were subjected to the standard CANMET tank test. The weld-metal corrosion and the heat-affected zone (HAZ) attack were analysed both by laser scanning and by contour measuring techniques.

LABORATOIRES DE LA TECHNCLOGIE DES MÉTAUX
RAPPORT 90-47(TR)

ANALYSES DE LA CORROSION DES SOUDURES À L'ARC AVEC ÉLECTRODE FOURRÉE EN UTILISANT UN DÉCHIFFREUR DE LASER ET UN TRAÇOIR DE CONTOURNEMENT

par

A.W. Lui et J. McGoey

RÉSUMÉ

Quinze soudures à l'arc avec électrode fourrée en combinaison avec divers fluxs ont été éprouvées dans le test de réservoir à CANMET. La corrosion du métal de soudure et de la zone affectée par la chaleur ont été analysées en utilisant un déchiffreur de laser et un traçoir de contournement.

INTRODUCTION

Weld-zone corrosion is of great concern in the marine vessel industries. In recent years, much work has been carried out in this laboratory. In this work, a new technique to analyse weld-metal attack and heat-affected zone attack on corroded surfaces by the use of a Hymarc laser scanner was initiated. The results were then compared with those from a Mitutoyo contracer measurement.

EXPERIMENTAL

Fifteen trapezoidal steel samples with flux-cored arc weldments (FCAW) were subjected to the standard CANMET tank test (1,2) for 6 months in a 3.5% NaCl solution held at 0-1°C. The composition of the welds and the baseplate are given in Tables 1 and 2. The samples were taken out of the tank at two-month intervals for profile measurements with the Mitutoyo contracer. The detailed procedure has been reported elsewhere (2). At the end of the 6-month period, the corroded samples were also analysed for attack by the use of the Hymarc laser scanner.

In the laser scanner system, a laser beam emitted from the aperture window of the unit scans across the surface of the corroded specimen. By digitizing the xyz components of a grid of points on the surface, it is able to detect pits and peaks and their location. The value of the pit depth and peak height are calculated with reference to an imaginary plane established by the operator by choosing up to 20 high points on the surface. The maximum pit depth, the mean depth of pits and the volume loss of material are used as criteria for corrosion interpretation.

RESULTS AND DISCUSSION

After six months tank testing, the weld metal corrosion, the HAZ attack and the surface roughness of the baseplates obtained by laser scanning analysis are given in Tables 3-5. The results measured by contact tracing at two-month intervals are given in Tables 6 and 7.

Welding consumables are often alloyed with Ni to reduce weld-metal corrosion problems. As shown in Fig. 1 and 2, the weld-metal attack decreased as the Ni content of the weldment increased. Samples E, F, O and J, having the highest Ni-content (2.0% range), are the most corrosion resistant in the group. Similar observations are noted in the 2, 4 and 6 month contact tracing of the sample (Figs. 4 and 5). However, these four samples also showed HAZ attack, and the HAZ attack appears to be inversely related to the weld metal attack (Fig. 3).

The values obtained by laser scanning are always higher than those obtained by contact tracing. In comparing the two sets of results, it should be noted that, in the contact measurement, the change of line-profile with exposure time (between two fixed reference points) is the criterion

for corrosion evaluation. The accuracy is limited by the diameter of the pit compared with the diameter of the stylus, the location of the subsequent profile-line in relation to the original profile-line and the number of significant pits picked up or missed by the profile-line. In laser scanning, the depression of points in a defined area in relation to a reference plane was calculated to 0.001 cm. The scanning density is 0.005 cm (2 thou) point spacing and 0.020 cm (8 thou) line spacing, and consequently will pick up all the significant pits on a scanned area. The other difference is that in laser scanning analysis, weld-metal corrosion and HAZ attack are mutually exclusive. The maximum pit depth or the mean depth or pits reported for weld metal is not necessarily the value of the HAZ. In contact measurement, because of the limited number of points, the weld-metal corrosion and the HAZ attack data sometimes overlap; in this case, the average value, particularly mean HAZ attack, will not be meaningful.

CONCLUSIONS

Weld metal corrosion in steel plates with FCAW deposits varies inversely with the Ni-content of the welding consumables. The most resistant samples are E, F, O and J which contain 2% Ni. Samples E, F, O and J are noted to have HAZ attack and the attack is inversely related to weld-metal corrosion.

Results from the laser scanner are always higher than those from the contact tracer. In view of their capabilities and limitations, results from the scanner are more representative of the corroded samples.

REFERENCES

1. Brigham, R., McLean, M., Donepudi, V.S., Santyr, S., Malik, L. and Garner, A. "Evaluation of weld-zone corrosion of shipbuilding steel plates for use in the Arctic environment"; Can. Met. Quart. 27:311; 1988.

2. Parkinson, L.D., Malik, L., Mitrovic-Scepanovic, V. and Brigham, R.J. "Evaluation of shield metal arc welding consumables for repair of weld-zone corrosion"; Can. Met. Quart 28:135; 1989.

Table 1. Chemical composition of the welds (spectrochemical analyses, wt %).

Flux type	Product-FCAW weld metal	C	Mn	P	Si	Ni	Mo	Co	Ti	Sn	Al	Nb	Cu	S	V
Basic	A	0.085	1.65	0.014	0.60	0.115	0.19	0.004	0.008	0.004	<0.001	0.008	0.02	0.15	0.004
	B	0.090	1.75	0.012	0.705	0.13	0.002	0.006	0.01	0.015	0.017	0.0075	0.04	0.015	0.006
	C	0.09	1.33	0.015	0.73	0.15	0.004	0.008	0.0095	0.003	0.01	0.006	0.02	0.010	0.020
	D	0.075	1.36	0.018	0.58	0.705	0.015	0.005	0.007	0.004	0.0005	0.007	0.03	0.023	0.006
	E	0.075	0.88	0.012	0.395	2.25	0.02	0.01	0.007	0.004	0.0004	0.0055	0.06	0.01	0.007
	F	0.050	0.95	0.020	0.444	2.34	0.02	0.01	0.008	0.004	0.001	0.0065	0.02	0.01	0.025
2nd generation rutile	G	0.060	1.28	0.010	0.34	0.72	0.007	0.005	0.03	0.006	0.001	0.010	0.05	0.010	0.020
	H	0.065	1.45	0.010	0.68	0.96	0.01	0.005	0.045	0.007	0.001	0.020	0.02	0.020	0.030
	I	0.065	1.34	0.015	0.53	0.04	0.004	0.0035	0.035	0.008	<0.001	0.010	0.04	0.010	0.020
	J	0.055	1.16	0.007	0.51	2.35	0.02	0.008	0.06	0.01	0.015	0.015	0.055	0.010	0.020
	K	0.055	1.47	0.015	0.40	1.74	0.02	0.007	0.07	0.004	0.001	0.015	0.03	0.015	0.020
Metal cored	L	0.050	1.39	0.005	0.82	0.04	0.01	0.003	0.040	0.007	0.03	0.007	0.05	0.010	0.006
	N	0.050	1.57	0.015	0.835	0.055	0.01	0.005	0.010	0.005	0.015	0.008	0.03	0.010	0.010
	O	0.045	1.09	0.015	0.33	2.00	0.02	0.013	0.008	0.004	0.001	0.009	0.035	0.015	0.030
Inner-shield	P	0.085	1.03	0.008	0.09	0.74	0.03	0.005	0.020	0	0.69	0.009	0.01	0.005	0.015

Table 2. Composition of baseplate steel (wt %)

C	Mn	Si	P	S	Cu	Ni	Cr	Mo	V	Nb	Al
0.10	1.24	0.23	0.012	0.010	0.05	0.07	0.04	0.02	0.044	0.039	0.051

Table 3. Weld-metal corrosion after six months tank testing
- by laser scanning analysis.

Plate	Max. pit depth (mm)	Mean pit depth (mm)	Standard deviation	Volume loss (cm^3/sq cm)
A	4.038	3.039	0.726	0.203
B	4.385	2.108	0.719	0.211
C	4.300	2.510	0.621	0.251
D	2.227	1.072	0.312	0.107
E*	1.402	0.158	0.278	0.028
F*	1.537	0.097	0.204	0.015
G*	1.825	0.543	0.376	0.056
H	2.294	1.206	0.408	0.121
I	3.875	2.392	0.574	0.239
J*	1.507	0.336	0.221	0.034
K	2.800	0.935	0.449	0.094
L	3.474	2.171	0.515	0.217
N	4.053	2.647	0.520	0.265
O*	1.855	0.159	0.139	0.016
P*	1.977	0.942	0.273	0.094

* with HAZ attack

Table 4. HAZ attack after six months tank testing - by laser scanning analysis.

Plate	LHS*		RHS*	
	Max. (mm)	Mean (mm)	Max. (mm)	Mean (mm)
E	1.902	0.923	2.275	1.008
F	2.029	0.773	2.513	1.054
G	2.022	0.935	--	--
J	1.683	0.715	1.716	0.697
O	2.323	0.856	1.881	0.960
P	2.844	1.384	2.505	1.062

* Corrosion was so severe that it is impossible to identify the HAZ with the first or last welding pass. LHS and RHS refer to the respective HAZ when viewing the trapezoid with the longer parallel line at the bottom.

Table 5. Surface roughness of steel plates after six months tank testing -by laser scannind analysis.

Plate	Max. pit depth (mm)	Mean pit depth (mm)	Standard deviation
A	0.919	0.170	0.142
B	0.729	0.106	0.078
C	0.746	0.219	0.124
D	0.661	0.084	0.132
E	0.905	0.162	0.017
F	0.694	0.110	0.106
G	0.952	0.304	0.178
H	0.685	0.159	0.098
I	0.990	0.220	0.183
J	0.590	0.189	0.107
K	0.994	0.337	0.181
L	0.926	0.112	0.128
N	0.760	0.184	0.093
O	0.891	0.292	0.159
P	1.236	0.167	0.166

Table 6. Maximum attack of FCAW deposit by profile-line analysis (mm).

Plate	Two months	Four months	Six months
A	0.92	2.08	3.18
B	1.16	2.12	2.92
C	1.14	2.40	3.56
D	0.82	1.44	1.61
E	1.10	1.36	1.80
F	0.77	1.12	1.54
G	0.66	1.20	1.78
H	0.68	1.38	1.84
I	1.08	2.28	3.26
J	0.77	1.18	1.18
K	0.66	1.14	1.41
L	1.02	2.12	3.02
N	1.14	2.20	3.54
O	1.20	1.30	1.42
P	0.99	1.08	1.76

Table 7. Mean attack of FCAW deposit by profile-line analysis (mm)

	Two-month		Four-month		Six-month	
Plate	Mean	Std. dev.	Mean	Std. dev.	Mean	Std. dev
A	0.70	0.15	1.30	0.47	2.10	0.73
B	0.80	0.22	1.33	0.54	1.67	0.78
C	0.83	0.20	1.52	0.59	1.94	0.92
D	0.40	0.14	0.73	0.34	1.01	0.20
E	0.13	0.28	0.26	0.23	0.45	0.25
F	0.05	0.11	0.18	0.22	0.29	0.25
G	0.14	0.15	0.28	0.31	0.75	0.41
H	0.40	0.14	0.68	0.39	1.04	0.40
I	0.75	0.25	1.38	0.43	1.84	0.82
J	0.11	0.19	0.23	0.31	0.31	0.29
K	0.27	0.20	0.47	0.21	0.62	0.32
L	0.76	0.19	1.38	0.55	1.79	0.76
N	0.85	0.14	1.70	0.44	2.10	0.78
O	0.13	0.28	0.29	0.35	0.32	0.24
P	0.27	0.15	0.60	0.20	1.02	0.24

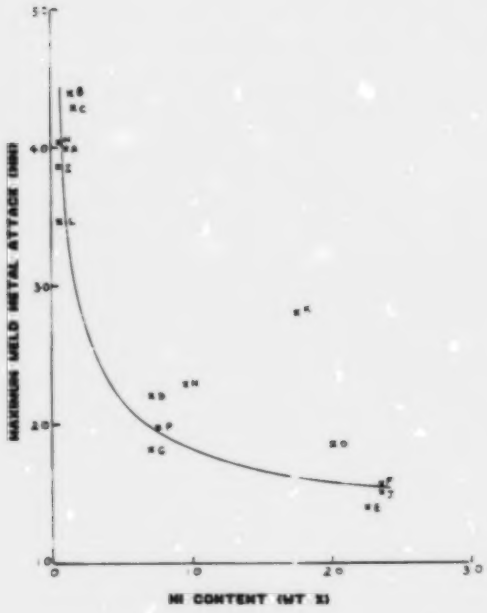


Fig. 1. Maximum weld metal attack as a function of Ni content. (neg 20545)

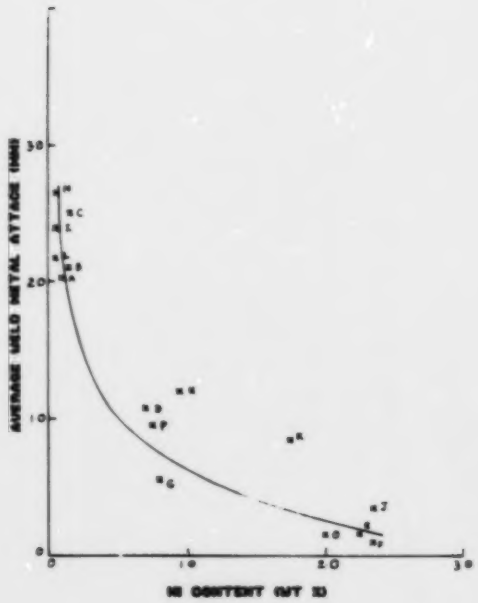


Fig. 2. Average weld metal attack as a function of Ni content. (neg 20541)

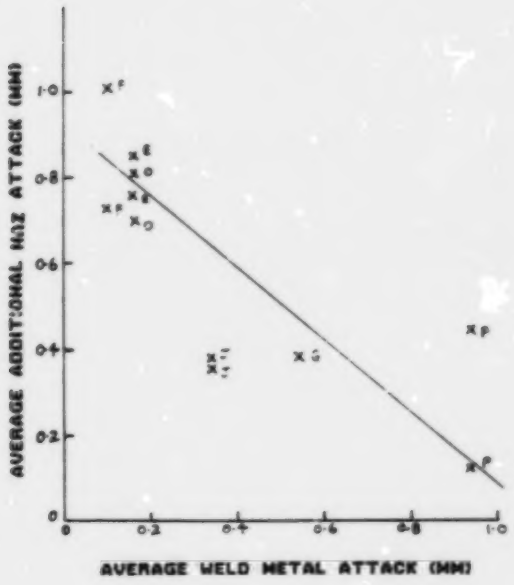


Fig. 3. Weld metal attack vs additional HAZ attack. (neg 20544)

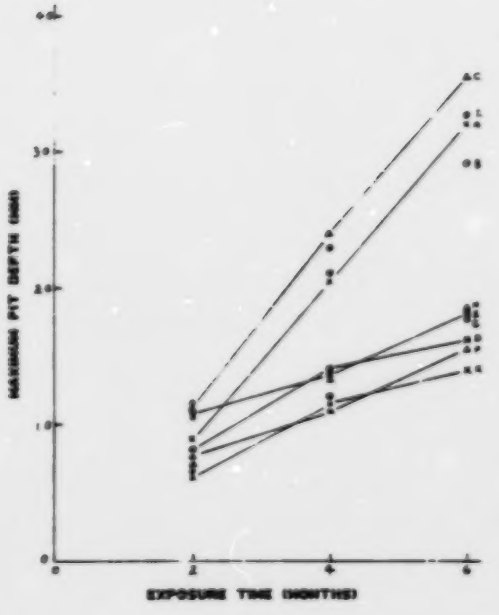


Fig. 4. Maximum pit depth vs time. (neg 20542)

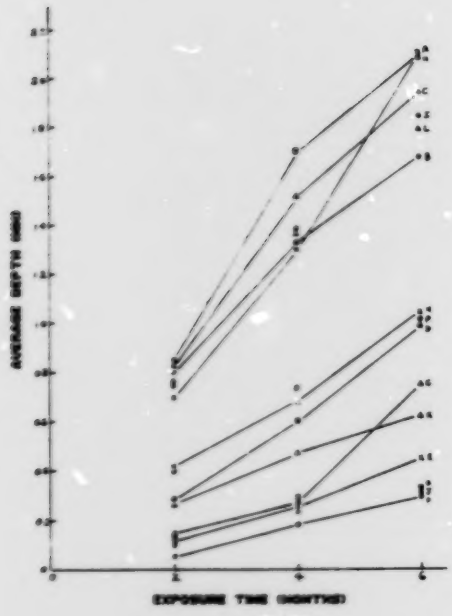


Fig. 5. Average depth of pits vs time. (neg 20543)